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PENSOFT

New record of the Six-holed Keyhole Urchin, *Leodia sexiesperforata* (Leske, 1778) (Clypeasteroida, Mellitidae), from the Brazilian coast, with an updated distribution map

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Abstract

A new record of *Leodia sexiesperforata* is reported from the coast of Rio Grande do Norte state, northeastern Brazil. An updated distribution map based on data collected from literature, museums, and scientific collections is also presented. This new report fills a distribution gap on the coast of northeastern Brazil. *Leodia sexiesperforata* has a continuous range between the states of Ceará and Alagoas.

Key words

Sand dollars; Echinoidea; distribution gap; Atlantic Tropical ecoregion.

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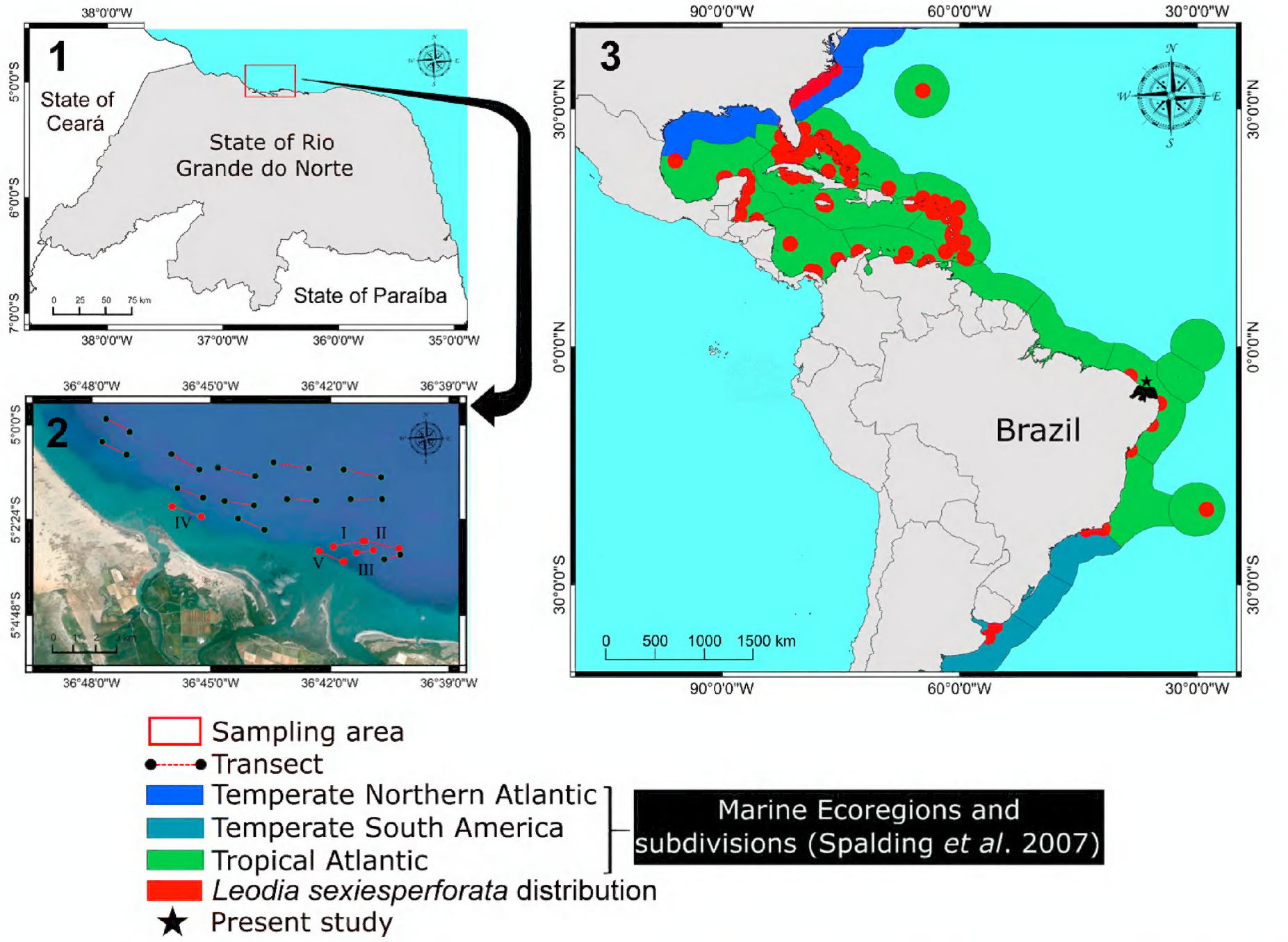
Introduction

The Six-holed Keyhole Urchin, *Leodia sexiesperforata* (Leske, 1778) (Clypeasteroida, Mellitidae), is an irregular Echinoidea with a wide distribution along the coast of the Americas, from eastern North America to Uruguay (Clark 1933, Mooi and Peterson 2000), with records from the United States of America, Mexico, Belize, Bahamas, Cuba, Puerto Rico, Barbados, Venezuela, and Brazil. Clark (1933) stated that this species occurs in Jamaica, Saint Kitts, Martinique, Saint Vincent, and Tobago. Herrera-Moreno and Bitencourt (2013) listed *L. sexiesperforata* as occurring in Honduras, Costa Rica, Dominican Republic, Panama, Colombia, and Uruguay. In Brazil, its distribution is widely known, but with some gaps, and has been recorded from the states of Ceará, Paraíba, Pernambuco, Alagoas, Bahia, Espírito Santo, and Rio de Janeiro (Rathbun 1879, Lima-Verde 1969, Alves and Cerqueira 2000, Ventura et al. 2006, Gondim et al. 2008, Miranda et al. 2012).

The Brazilian Northeastern Region extends for over 19 degrees in latitude (between 01°02′30″ N and 18°20′07″ S), comprising a coastline of approximately 3400 km, and holding a wide variety of coastal environments such as beaches, dunes, cliffs, estuaries, deltas, sandbanks, islands, and coral reefs, among oth-



Figures 1–3. Sampling site in Rio Grande do Norte (1 and 2) and updated distribution map (3) for *Leodia sexiesperforata* (Leske, 1778). Highlighted transects sampled in the species collection campaign (Roman algorism) and marine realms, and their subdivisions proposed by Spalding et al. (2007).

ers (Pinheiro et al. 2008). In this region, pioneering work includes the publications of Verrill (1868), studying material collected in Abrolhos Archipelago, Bahia coast; Rathbun (1879), with collections conducted in several sites of the Brazilian coast including the northeastern region; and Lima-Verde (1969), with collections from Piauí (Parnaíba river mouth) to Alagoas (São Francisco river mouth).

Recently faunistic inventories of Echinodermata in northeastern Brazil have been published for the following states: Maranhão (Gondim et al. 2013), Piauí (Gondim and Giacometti 2010, Gondim et al. 2013), Ceará (Martins and Queiroz 2006, Manso et al. 2014), Paraíba (Gondim et al. 2008, Gondim et al. 2014a), Pernambuco (Fernandes et al. 2002, Lima and Fernandes 2009), Alagoas (Lima et al. 2011, Miranda et al. 2012), and Bahia (Alves and Cerqueira 2000, Magalhães et al. 2005, Manso et al. 2008). The few data from Sergipe state comes from an inventory by Oliveira et al. 2010, who also includes materials from other states in the Northeast Region such as Paraíba, Alagoas, and Bahia. For Rio Grande do Norte, until now, publications are Lima-Verde (1969) with samples in Rocas Atoll and in Maracajaú beach, and Gondim et al. (2012, 2014b, 2015a, 2015b, 2015c) and Manso et al. (2014) with samplings conducted from the continental shelf.

Despite the above-mentioned papers, the knowledge of echinoderm biodiversity in Brazil remains sparse (Ventura et al. 2006), especially in the Northeastern Region (Miranda et al. 2012). Thus, the aim of this paper is to report the first record of *L. sexiesperforata* from the coast of Rio Grande do Norte and provide an updated distribution map based on literature and field samples.

Methods

Between June 2013 and February 2015 seasonal benthic biodiversity expeditions were conducted on the shallow continental shelf off the Porto do Mangue region of Rio Grande do Norte, northeastern Brazil (Fig. 1). The timing of the surveys was determined based on the historic rainfall data for Porto do Mangue municipality over a period of 10 years (1992–2012) provided by EMPARN (Empresa de Pesquisa Agropecuária do Rio Grande do Norte). Thus, the expeditions were scheduled for the dry (March–May and June–August) and rainy season (September–November and December–February). In each expedition, trawl fishing for biological collections was conducted at georeferenced sites (Fig. 2) by utilizing an artisanal trawl fishing boat. In addition, environmental data were collected, including depth (in meters), water transparency, temperature, salinity, dissolved oxygen, and pH from the water

column bottom. The capture effort in each site had 20 min duration at an approximate speed of 2 knots, with a 4 mm mesh fishing net reaching the bottom.

The sand dollars were identified following what was introduced by Tommasi (1966) and Hendler et al. (1995). Later, the specimens were stored in 70% alcohol and deposited at the collection of Grupo de Estudos em Ecologia e Fisiologia de Animais Aquáticos (GEEFAA), with the voucher number GEEFAA/UFRN-361.

Collection data from this study (primary data) were compiled along with a bibliographic survey (secondary data) to prepare an updated distribution map of *L. sexiesperforata*. Geographic coordinate data were gathered information from 2 different sources. The first source was the reviewing of publications, lists of specimens, biodiversity surveys, and scientific reports (Table 1). The second source was the revision of deposited material in scientific collections of research institutes and museums accessible through the Global Biodiversity Information Facility (GBIF 2013). Records without precise taxonomy, invalid geographic coordinates, or missing information on the collection and the institutions to which they belonged were disregarded. Fossils were ignored as well, because they escaped the goal of this survey. Lastly, occurrences having no geographic coordinates but with satisfactory sampling location details had their location estimated using Google Earth Pro® software version 7.1.2.2041.

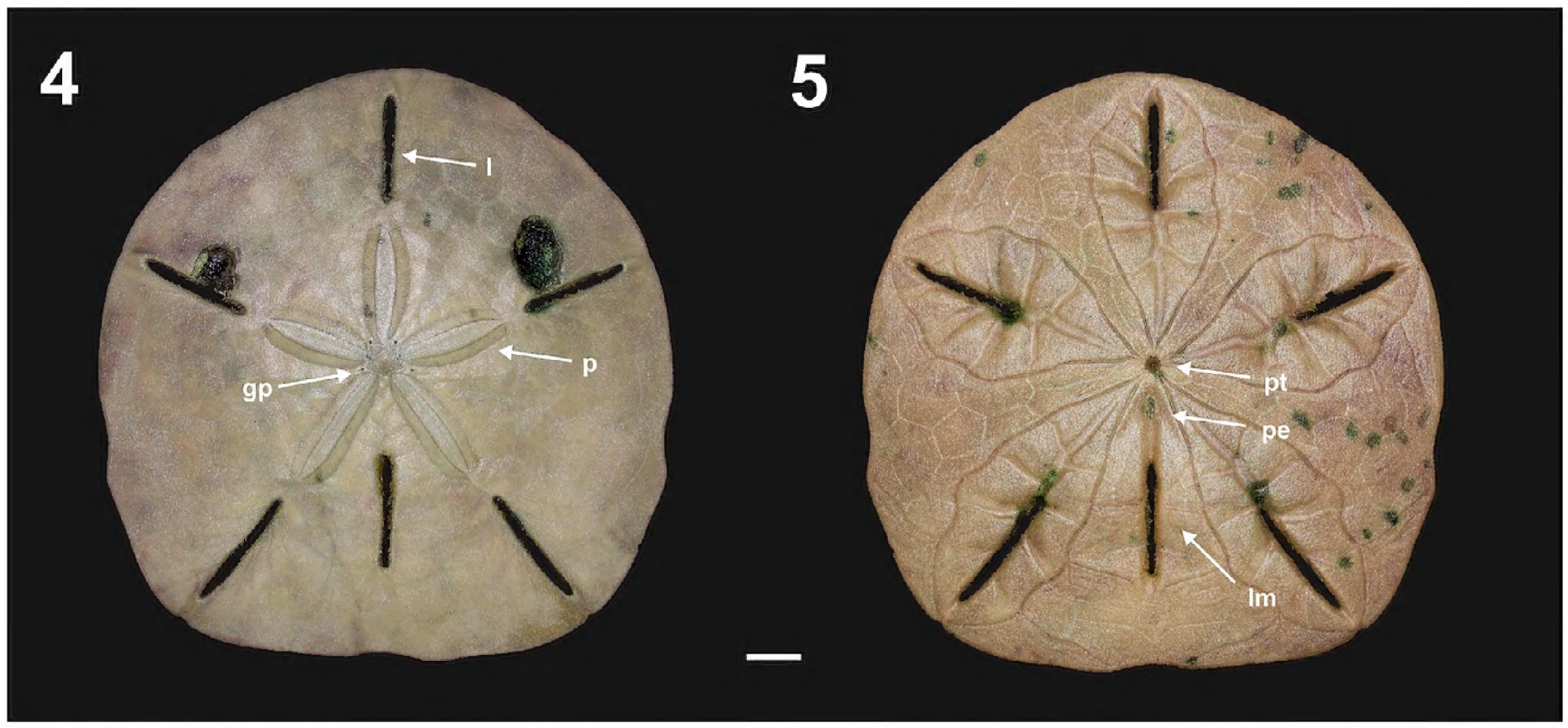
Facilities consulted using the GBIF directory were: California Academy of Sciences (CAS), Centro de Investigación y de Estudios Avanzados Unidad Mérida, Instituto Politécnico Nacional (CINVESTAV-IPN), Florida Museum of Natural History (FLMNH), Colección Nacional de Equinodermos Mexicanos (ICML-DF, UNAM), Museo Argentino de Ciencias Naturales "Bernardino Rivadavia" (MACN), Marine Resources Research Institute (MRRI-SCDNR), Museum of Comparative Zoology, Harvard University (MCZ), Natural History Museum Rotterdam (NL), National Ocean and Atmospheric Administration–National Benthic Inventory (NBI-NOOA 2001 Grays Reef National Marine Sanctuary), REVIZEE Project Central Score (Lavrado and Ignacio 2006), and National Museum of Natural History, Smithsonian Institution (NMNH DwC-Archive, information provided with the permission of the NMNH).

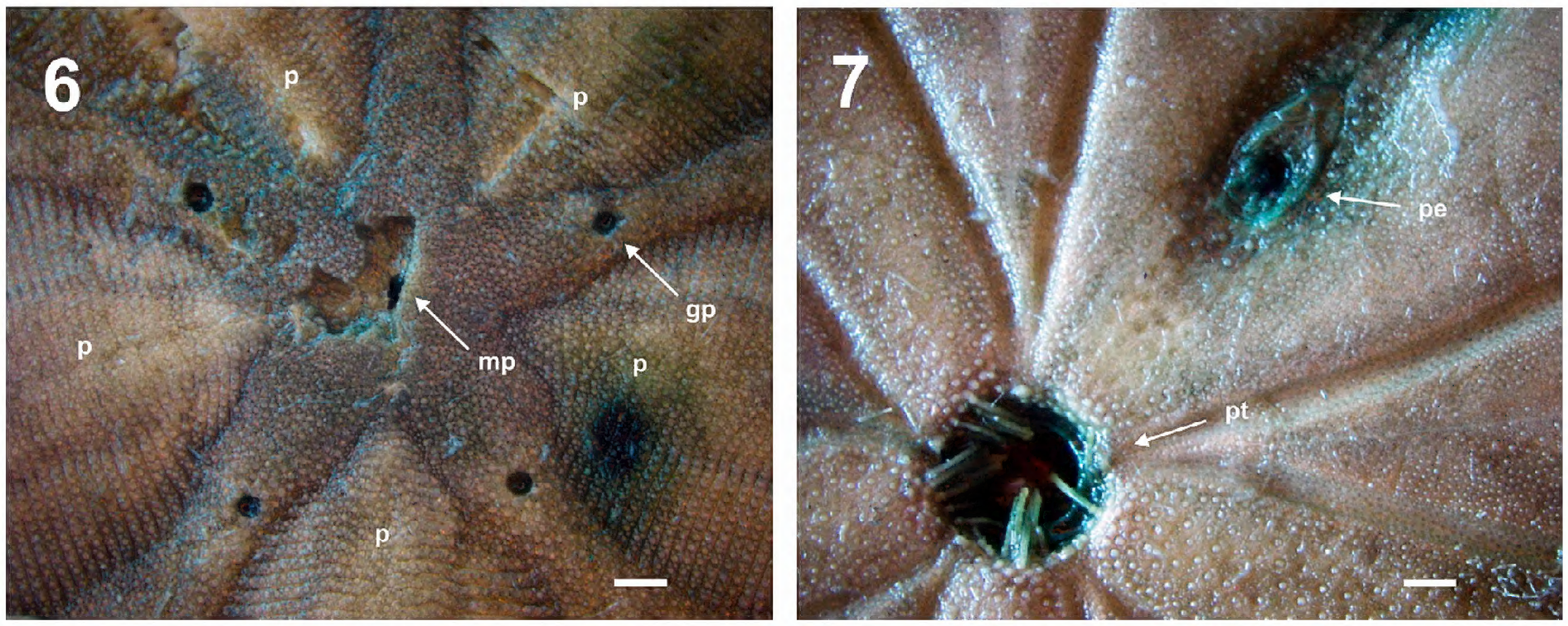
All obtained data (primary and secondary) were compiled and added to a geospatial database, and the

Table 1. *Leodia sexiesperforata* occurrences from literature data. Present study highlighted in bold.

Author(s)	Locality (State)	Country	Latitude	Longitude
Mooi (1986a)	New Brunswick (North Carolina)	USA	33°42′56.14″ N	078°13′24.48″W
	Florida Keys (Florida)		24°29′16.82″ N	081°45′56.89″W
Mooi (1986b)	Pigeon Key (Florida)	USA	24°42′5.99″ N	081° 9′16.86″W
Telford & Mooi (1986)	Long Key (Florida)	USA	24°48′30.68″ N	080°48′59.24″W
Solis-Marin et al. (2011)	NA*	Mexico	NA*	NA*
Kier (1975)[1]	Carrie Bow Cay	Belize	16°48′ N	088°05′W
McClintock & Marion (1993)[1]	San Salvador	Bahamas	24°04′ N	074°35′W
Campos & Solis-Marin (1998)[1]	Baía de Cardenas	Cuba	23°00′ N	081°16′W
Clark (1933)	Arroyo	Puerto Rico	17°57′22.91″ N	066°04′13.53″W
Telford (1978, 1982)	Rockley Beach (Bridgetown)	Barbados	13°4′20.44″ N	059°35′21.15″W
Zoppi de Roa (1967)[2]	Golfo Cariaco	Venezuela	10°30′24.63″ N	064°4′10.95″W
	Cumaná		10°27′22.97″ N	064°14′58.40″W
	Isla de Coche		10°45′04.03″ N	063°58′7.83″W
	Bahía de Mochima (Sucre)		10°17′47.75″ N	064°30′13.89″W
	Cata (Aragua), Playa Grande (Vargas), Quizandal (Carabobo), Punta Morón (Carabobo)		10°34′14.30″ N	067°47′32.47″W
	Archipielago de los Roques		11°48′32.88″ N	066°48′34.57″W
Edwards (1973)[2]	Cumaná	Venezuela	10°27′22.97″ N	064°14′58.40″W
Lima-Verde (1969)[1]	Meireles Beach (Ceará)	Brazil	03°43′09.34″ S	038°29′29.48″W
Present study	Porto do Mangue (Rio Grande do Norte)	Brazil	05°02′18.6″S	036°45′14.3″W
Gondim et al. (2008)[1]	Cabo Branco Beach (Paraíba)	Brazil	07°08′50″ S	034°47′51″W
Rathbun (1879)	(Pernambuco)	Brazil	NA**	NA**
Miranda et al. (2012)[1]	Francês Reef (Alagoas)	Brazil	09°46′03″ S	035°50′13″W
Queiroz et al. (2011)[1]	Praia de Porto da Barra (Bahia)	Brazil	13°00′24″ S	038°31′48″W
Alves & Cerqueira (2000)	Salvador (Bahia)	Brazil	13°01′26.36″ S	038°30′30.47″W
Magalhães et al. (2005)	Baía de Todos os Santos, Praia de Itapuan, Praia da Ribeira (Bahia)	Brazil	13°01′26.36″ S	038°30′30.47″W
Manso et al. (2008)[1]	Baía de Todos os Santos (Bahia)	Brazil	12°51′18.85″ S	038°36′25.87″W
Ventura et al. (2006)[1]	Ilha Martin Vaz (Espírito Santo)	Brazil	20°30′46.8″S	028°50′31.2″W
Rathbun (1879)	Baía do Rio de Janeiro (Rio de Janeiro)	Brazil	22°46′35.46″ S	043°07′48.78″W

[1] Original geographic coordinates (other coordinates were estimated, see Methods for further information).
[2] Apud Francisco and Pauls (2008).
* Locality and geographic coordinates not avaliable.
** Geographic coordinate not avaliable.
NA: Not avaliable.





Figures 4–7. *Leodia sexiesperforata* (Leske, 1778). **4.** Aboral view. **5.** Oral view. **6.** Detail of the apical system. **7.** Detail of the central region in the oral view. l = lunule, p = petals, gp = genital pore, pt = peristoma, pe = periproct, lm = median posterior lunula, mp = madreporite plate. Scale bars 4 and 5: 10 mm. Scale bars 6 and 7: 1 mm.

resulting tables were imported into QuantumMap 2.14.0 (QGIS Development Team 2016) software using the datum WGS84. Marine ecoregion delimitations, as proposed by Spalding et al. (2007), were added. These were obtained through the Marineregions.org (http://www.marineregions.org) online portal. Lastly, each occurrence of the species underwent a 1° buffer, and the final updated geographic distribution map of *L. sexiesperforata* was generated.

Results

Class Echinoidea Leske, 1778
Order Clypeasteroida Agassiz, 1872
Suborder Scutellina Haeckel, 1896
Family Mellitidae Stefanini, 1912
Genus *Leodia* Gray, 1851

Leodia sexiesperforata (Leske, 1778)

Material examined. Brazil: Rio Grande do Norte: shallow continental shelf of Rio Grande do Norte, Porto do Mangue municipality, 2 specimens, 05°02′18.6″ S, 036° 45′14.3″ W, 3-II-2015, (voucher GEEFAA/UFRN 361) (Figs 4–7).

Additional material. Brazil: Paraíba: Beach rocks ferruginous sandstone, Cabo Branco Beach, João Pessoa municipality, 07°08′50″ S, 034°47′51″ W, voucher UFPB.ECH 1163 (Gondim et al. 2008).

Diagnosis. Test subcircular, flat, dorsally elevated in middle portion, with thin delicate edge and flat oral surface (Figs 4, 5). Five short petals, similar in length (Fig. 4). Apical disk with 4 genital pores (Fig. 6). Six similar lunules, narrow and elongate, including 5 ambulacral lunules and 1 anal lunule (Figs 4, 5). Peristome situated in middle of oral surface (Fig. 5). Periproct placed in the oral region between peristome and the anal lunule and positioned closer to peristome (Fig. 7).

One specimen of *L. sexiesperforata* was captured at site IV and another at site V, both during the 2015 December–February expedition (sample in February) (Fig. 1). These

specimens represent the first record of this species from the Rio Grande do Norte coast (Table 1). Both sample sites IV and V presented similar abiotic factors such as depth, salinity, dissolved oxygen, and pH. Water transparency and bottom temperature were equal at both sites (Secchi = 1.5 m, Temperature = 28.5 °C). Average depth at both sample sites was 3.5 m (Table 2). In addition, the region where both sites are located is mostly formed by predominantly sand sediments.

Discussion

The geographic distribution of *L. sexiesperforata* is situated entirely within 3 marine realms: Temperate Northern Atlantic, Tropical Atlantic, and Temperate South America (Fig. 3). The Temperate Northern Atlantic shows a predominance of records from the east coast of the United States, Carolinian Ecoregion. In the Tropical Atlantic, the data comes from 2 broad areas divided by an extensive gap. The first is in the Caribbean and along the southeastern coast of the United States (Tropical Northwestern Atlantic province), with the most number of occurrences of *L. sexiesperforata*. The second area extends from the Brazilian Northeast Region as far south as the Cabo Frio resurgence zone at the southern limit of the Tropical Southwestern Atlantic province, Rio de Janeiro; here information is sparse and there are multiple gaps in the known distribution of *L. sexiesperforata*. Between these 2 areas the North Brazilian Shelf province (from the state of Piauí to Venezuela) has no record of this species. Lastly, records of *L. sexiesperforata* are known from the Warm Temperate Southwestern Atlantic province, with a distribution gap between the Brazilian Southeast Region and Uruguay (Fig. 3).

The new record of *L. sexiesperforata* from Rio Grande do Norte fills the gap in the known distribution of the species. Therefore, the distribution of this species extends continuously along the Brazilian Northeast coast from Ceará to Alagoas. Recent studies, such as by Gondim et al. (2013) with material collected along the coast of Maranhão and Piauí and Oliveira et al. (2010), who includes few materials collected on the coast of Sergipe, have not reported the occurrence of *L. sexiesperforata*, but this might be due to a lack of sampling.

The distribution gaps of macrobenthic species on the northeast Brazilian coast may be due to the sparsity of surveys, although there has been an increase in recent records. This is particularly highlighted along the coast of Rio Grande do Norte state, where recent surveys for benthic biodiversity and accidental sampling has accounted for new records (Gondim et al. 2012, 2015a, 2015b, 2015c, Manso et al. 2014, Moraes et al. 2015) and ecological interactions (Alencar et al. 2014). Thus, continuous benthic biodiversity surveys along the Brazilian northeast coast is paramount for a better understanding of the geographic distribution of *L. sexiesperforata*.

It is known that Echinodermata have a fundamental role in marine environments (Benitez-Villalobos 2001), occupying several trophic levels in the food chain (herbivore, carnivore, detritophage, and omnivore), regulating the density of species, participating in the recycling of nutrients, bioerosive processes, and even in the epibiosis with other animals and plants (Caso 1978, Hadel et al. 1999, Ventura et al. 2006). Therefore, new records, such as those presented hereby, not only contribute to a better knowledge of the fauna but also aid in evolutionary and marine conservation studies.

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Authors' Contributions

CERDA wrote the text, identified the specimens, and prepared the figures and tables; VFV collected the data, revised literature, and wrote the text; SASNM collected the data, wrote the text, and made the figures and tables; PVNA wrote the text, and made the figures and tables; FAMF identified specimens, reviewed literature, wrote the text, and revised the text.

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Table 2. Abiotic factors in each sample point where *Leodia sexiesperforata* was captured. CLT = current local time, Dep = depth, Secchi = water transparency, T = bottom temperature of the water column, Sal = bottom salinity of the water column, DO = dissolved oxygen.

	Latitude	Longitude	CLT (GMT –03:00)	Dep (m)	Secchi (m)	T (°C)	Sal	DO (mg/L)	pH
Transect IV	05°02'18.6" S	036°45'14.3"W	12:10	3.8	1.5	28.5	37.38	5.23	8.77
	05°02'3.7" S	036°45'58.5"W							
Transect V	05°03'26.8" S	036°41'39.8"W	11:05	3.2	1.5	28.5	36.69	5.97	8.91
	05°03'11.2" S	036°42'17.5"W							

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